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THE MOSASAUR
The Journal of the Delaware Valley Paleontological Society

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COVER — A reconstruction of the terrain at the Port Kennedy, Pennsylvania, sinkhole that preserved a Late Irvingtonian fauna and flora. (See the paper by Daeschler, Spamer, and Parris in this volume.) Rendered by Bruce Mohn, Copyright © Bruce Mohn.

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Review and New Data on the Port Kennedy Local Fauna and Flora (Late Irvingtonian), Valley Forge National Historical Park, Montgomery County, Pennsylvania

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ABSTRACT — A late Irvingtonian assemblage of fossils at Port Kennedy, Montgomery County, Pennsylvania (today within the Valley Forge National Historical Park) was discovered in a filled solution feature first exposed in a quarry wall in 1870. The remnants of the deposit are buried today. Yielding specimens mostly of vertebrates, but including plants and beetle fragments, the deposit was well-studied by scientists of the late 1800s, most notably Edward Cope. In the last century, only systematically focused papers and reviews of Pleistocene faunas have discussed the Port Kennedy fossils. Mention of the plant material is made only in passing, and nothing more has been said of the (now missing) insect specimens. Furthermore, nothing has been discussed of the geology and taphonomy of the deposit and its fossils with the perspective of current geologic principles. This paper summarizes in this more modern view the known information about the deposit and its fossils. Revised and new information on taxonomy and status of specimens is provided, including new records and notice of the recovery of the holotype of the skunk *Brachyprotoma obtusata* (Cope, 1899) (Mammalia: Carnivora).

Introduction

IN 1871, TWO PAPERS (Wheatley, 1871; Cope, 1871) were published announcing the discovery of an interesting assemblage of "Post-Pliocene" fossils in a fissure deposit exposed in a quarry at Port Kennedy, Upper Merion Township, Montgomery County, Pennsylvania. The flora and fauna from this deposit offer a rare glimpse of the biota living in southeastern Pennsylvania during the late Irvingtonian Land Mammal Age (Mid-Pleistocene). Kurtén & Anderson (1980) refer this assemblage to the Aftonian Interglacial Stage or Kansan Glacial Stage. The deposit is roughly 500,000 years old. Other sites of similar age in eastern North America, exclusive of Florida, are Hanover Fissure No. 1 Quarry in Pennsylvania (Guilday et al., 1984), Cumberland Cave in Maryland (Gidley & Gazin, 1938), and Hamilton Cave (Repenning and Grady, 1988) and Trout Cave (Guilday, 1967; Grady, 1981) in West Virginia. Unfortunately, what remained of the Port Kennedy deposit was buried when the abandoned quarry was filled in.

The so-called "cave" alluded to in the literature can be interpreted more accurately as a sinkhole. This filled-in, buried feature was discovered during quarrying operations in the Ledger Formation (Cambrian), in what today is Valley Forge National Historical Park (Fig. 1A). The quarry, on the land of John Kennedy, was operated to process the lime content of the formation known then as the "Auroral Limestone" (or as Cope, 1871, referred to it, the "Potsdam limestone," "Potsdam" being a now-antiquated time-stratigraphic term). During quarrying, solution features were often encountered in the limestone. Wheatley (1871) reported that none of these other caves contained organic remains since they had had no direct communication to the open air. However, in 1870 quarrymen cut into a filled solution feature and, while digging through the fill, they came upon fossils. A mastodon tooth, probably unrecognized as such by the workers, was brought to one Dr. Quick of Phoenixville, who brought it to Wheatley. The two men immediately went to the quarry where they saw the remnants of a vase-shaped solution feature measuring more than 40 feet deep, with an original surface opening of 20 feet (Fig. 2). The deposits overlying the fossiliferous part of the fill were of a chaotic type typical of the sinkhole debris infill, here consisting of eroded sediments of the Triassic Stockton Formation that overlies the Ledger Formation. The fossils were found in clay and sand layers near the bottom of the exposure.

Shortly after Wheatley's (1871) announcement of the Port Kennedy discovery, Cope (1871) presented a "preliminary report" of the vertebrate remains from the deposit. That paper is primarily one of taxonomy, where Cope named several taxa new to science, but he concluded it with a section on "general observations." There he discussed the evolutionary placement of the remains of "postpliocene" faunas generally, providing additional evidence for a submerged trans-Pacific continent and an ice-free link to the west to effect the Pleistocene biogeographic dispersal of species.

Not for another two decades, however, would the Port Kennedy deposit play anything but a supporting role in the scientific literature, mostly in Cope's work on vertebrate systematics. In each autumn of 1894-1896, the quarry, then rather larger than in 1870, was revisited. Equipment was brought in to reopen the sinkhole, now again freshly exposed after workers had lowered the quarry floor by 12 feet. The objective was for collectors to retrieve whatever additional fossils could be obtained from the deposit, particularly human remains if they existed therein (Mercer, 1899). The reexcavation was in immediate response to the discovery by D. N. McCadden of fossils in a newer spoil heap. McCadden had brought the fossils to Mercer's attention, and the spoils were

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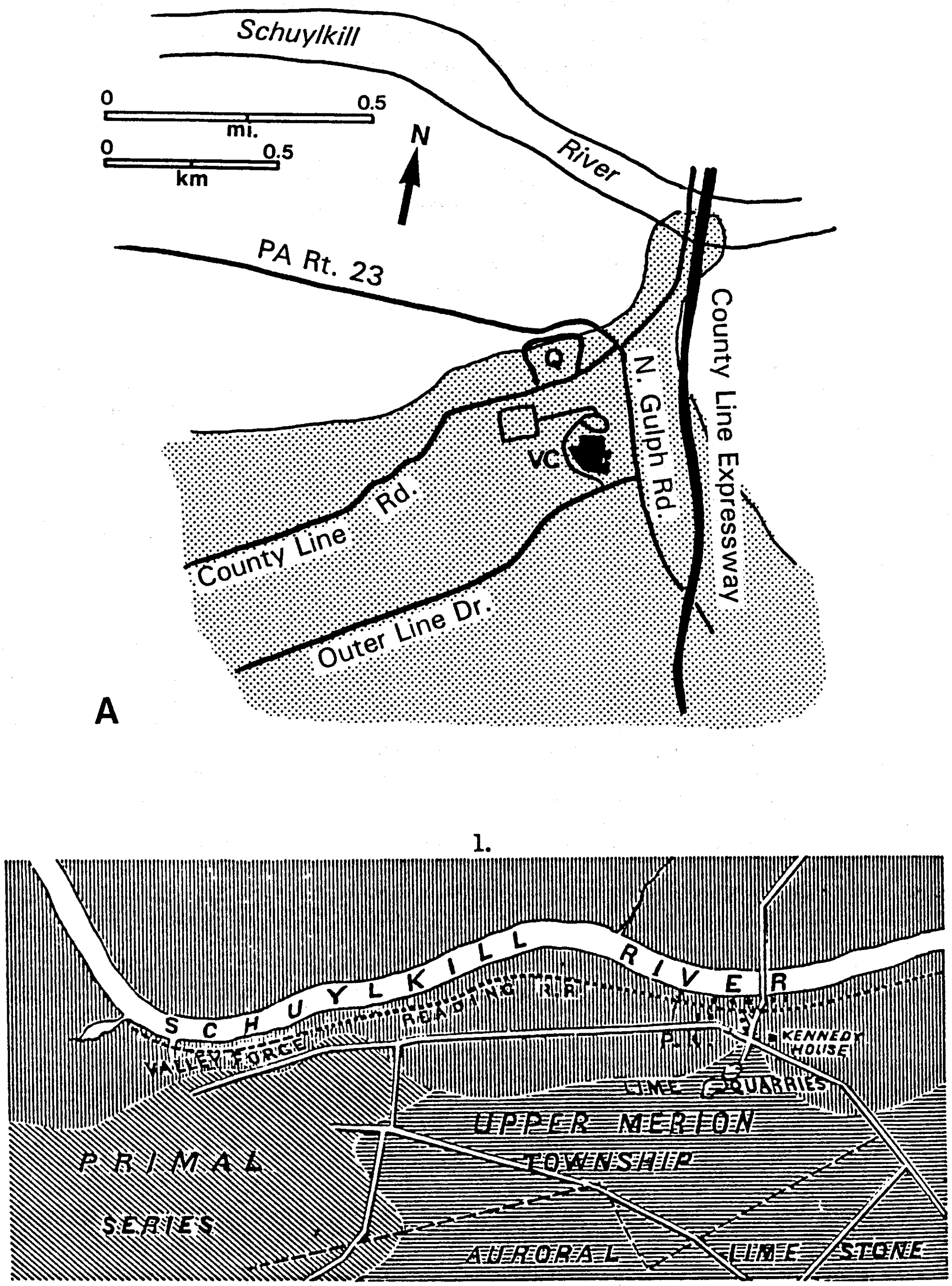

B Map of the region, showing the position of the Lime Quarries and cave; area lined vertically, is region of Mesozoic red shale; horizontally, of Auroral limestone; obliquely, of Primal sandstone.

Figure 1. Maps of the Port Kennedy area, southeastern Pennsylvania. **A**, Geographic and geologic map of the vicinity of the Port Kennedy quarry (in top center 1/9 of USGS Valley Forge, Pa., 7.5′ quadrangle). Surfcial geology after work compiled by A. A. Socolow in 1978 (in Berg and Dodge, 1981, p. 591). Shaded area delineates the area of the Cambrian Ledger Formation; the unshaded area maps the Triassic Stockton Formation. Q = Port Kennedy quarry discussed by this paper. VC = Visitors Center, Valley Forge National Historic Park. The most likely position of the buried fossil deposit is in the SE corner of the quarry. **B**, Wheatley's (1871, fig. 1) original map of the area, showing location of "lime quarries" near Port Kennedy ("P.K."), southwest of "Kennedy House."

for a while more closely examined by S. N. Rhoads of the Academy of Natural Sciences.

The reexcavation was carefully organized by H. C. Mercer, a Doylestown archaeologist, using field recording techniques that foretell modern methods. Still, the excavators did not succeed in mining out the whole deposit because groundwater continuously flooded the quarry floor despite the use of pumps during daily work there.

The two excavations of the Port Kennedy sinkhole deposit are one of the most interesting paleontological projects of the late nineteenth century. And from those efforts we have some field data, not common from paleontological excavations of that time, with which we can make some interpretations of deposition and taphonomy of the Port Kennedy Local Fauna and Flora.

The significant publications that describe the Port Kennedy deposit are Wheatley's (1871) and Cope's (1871) inaugural papers, and the reinvestigative papers by Mercer (1895, 1899) and Cope (1895, 1896), as well as Cope's (1899) posthumously published monograph on the vertebrate fossils. From these papers we have virtually our total understanding of the organic and sedimentologicalcontents of the deposit; a few of the specimens with matrix still attached provide some supporting data today. Nothing since Mercer's (1899) paper has been mentioned of the plant material, and only one paper (Horn, 1876) has ever described the few insect remains from the deposit. Not since the late nineteenth century has the deposit been looked at in its entirety. With a modern view, we here reintroduce this remarkable fossil assemblage to the research community.

We wish to point out that this paper is not one of wholesale systematic revision of the Port Kennedy biota, although we do present new and revised information on taxonomy and status of specimens. We also report some new records. Some of the systematic groups, we acknowledge, are not as well understood as many workers would like, but revisions are better handled by researchers of those groups so we avoid introducing revisions in the less well understood groups. We collate here for the first time all that is known of the Port Kennedy deposit. We present a fresh view of the fauna and flora, and consider depositional and taphonomic processes. But, by necessity, this is a preliminary reinvestigation. As explained in the concluding section on "Continued Work," the precise series of provenance data still remain to be arranged, and, ideally, the deposit itself should be relocated to establish the feasibility of its reexcavation a century after the last work there.

Abbreviations of repositories cited in this paper are: AMNH—American Museum of Natural History; ANSP—Academy of Natural Sciences of Philadelphia.

Identification of the Locality

The location of the sinkhole that yielded the Port Kennedy fossils is not known with precision today. Contemporary publications did not identify the locality with precision, and no attempt has been made since then to precisely reidentify the location of the deposit. Based on published documentation and additional historical information, we are, however, fairly certain in which of the several quarries in the area it was located.

During the nineteenth century, quarries and limekilns were common in the vicinity of Port Kennedy (see, for example, Woodman's [1922] history of Valley Forge). The quarry of interest here was in 1870 owned by John Kennedy (Wheatley, 1871). An 1871 atlas of Montgomery County (Hopkins and Co., 1871) shows several limestone quarries and properties owned by "J. Kennedy," including the one which is most likely the site of the fossiliferous sinkhole. By 1893, the time that the deposit was reopened, the property in question, although still marked as a quarry, was owned by the Montgomery Iron Co. (Smart, 1893). By sometime after 1904, this quarry and the one adjacent to it were no longer labelled as working quarries; both then were on the property of John Wilkinson (Franklin & Clarke, post-1904). An undated property map also shows that the quarry was divided by the property line between the land of Archibald B. Irwin and the "Ehret. Magnesia Co. formerly Emma C. Spear Lime Stone Quarry."

Two adjacent limestone quarries are indicated on Wheatley's (1871, fig. 1) original map (see also Fig. 1B herein). Without this generalized map we might not have any idea of the location of the quarry in question within the Port Kennedy area. None of the Port Kennedy publications precisely locate the fossil deposit within the quarry. Fortunately, the arrangement of roads on the available maps is unchanged today, and this is of great help in identifying the quarry. The roads and former railroad all followed a natural depression that made for ease in adjacent quarrying, lime processing, and transportation (see in Woodman, 1922), thus these pragmatic concerns have helped preserve the means by which we identify the site of this important fossil deposit.

With the quarry location established to within a few hundred meters, we identify the quarry with the fossil-bearing deposit as one of two that (although partially filled in now) still exist along County Line Road 0.3 km northwest of the present National Park Service Visitors Center in Valley Forge National Historical Park. The quarries are 0.2-0.3 km southwest of the intersection of Pennsylvania Route 23 and County Line Road. A rail spur, seen on most maps, served the quarry area; the line paralleled (and in one place was in) County Line Road, but the abandoned rails and ties were removed around 1980. The two quarries are separated by a low ridge that at one time was used as an accessway for vehicles that loaded railroad cars with limestone. The quarry area is not known to have had any historical significance to the Continental Army encampment of 1777-1778, during America's fight for independence.

Wheatley (1871) and Mercer (1899) provide exquisitely detailed descriptions of the sinkhole, lacking precision only in its location within the quarry. We can interpret the viewing angle toward the exposed deposit from the dip of the limestone (Wheatley, 1871, fig. 2). But only from Mercer's (1899) description of the size of the quarry can we establish which of the two pits contained the sinkhole. Mercer (unpublished notebook, ca. 1894?, in the Mercer Museum, Doylestown, Pennsylvania) provided linear measurements of the quarry—340 by 49 paces. Even with such generality, we believe that this is the more easterly of the two pits; both Mr. Brian Lambert of Valley Forge National Historical Park and one of the authors (E.E.S.) paced off the site in April 1990, when the two senior authors visited the locale with Mr. Lambert. The dimension of the pit measured from the old railbed to the back quarry wall in the easterly (larger) pit closely agrees in "paces" to Mercer's measurement; the westerly (smaller) pit is too small. The lengthwise dimension of the pit parallel to the old railbed is greater than Mercer's measurement, but this may be attributed to the probability that the quarry was made larger after 1896.

Geology of the Quarry

Two geologic formations predominate in the quarry area of Valley Forge National Historical Park: the Ledger Formation (a gray- to cream-colored Cambrian carbonate unit), and the Stockton Formation (a red sandstone of the Triassic part of the Newark Supergroup). The wide expanses of the park are a geomorphic expression of the Ledger Formation. The quarries of the Port Kennedy area are along the strike line of the angular unconformity between the Ledger and Stockton Formations (Socolow in Berg & Dodge, 1981).

Based on Wheatley's (1871, fig. 2) diagram of the sinkhole (Fig. 2A herein), we take note of the dipping limestone beds and thin veneer of nearly horizontal Stockton beds above them. Practically, we must interpret the figured dip angle as generalized, probably showing neither precise dip angle nor true dip direction. (Alternatively, the dip depicted in the diagram may be so generalized as to not even show the correct direction of apparent dip. We must assume that, since the observations of the various early authors were so good in other respects, the direction of dip is correctly shown.)

Good exposures (although becoming weathered and overgrown) of dipping beds are seen today in the Visitors Center lower parking lot 0.2 km SSW of the quarry, where the dip is to the south-southeast. The area hosts no structural elements that would affect dip angles over short distances. Thus any apparent dip to the right (as in Wheatley's diagram) would be seen in an easterly or northeasterly quarry wall. The overlying Stockton Formation is eroded away south of the quarry; at the quarry itself it is still present in some thickness on the exposed northwesterly wall. A thin veneer such as shown in Wheatley's diagram would be seen on a southerly to easterly side of the quarry, where it would be thin due both to regional erosion and to quarry operations. (Alternatively, the Stockton veneer may not have been present directly above the exposed sinkhole, and Wheatley's diagram may illustrate only the generalized stratigraphic relationship of the two units there.)

The form of the sinkhole itself may be an indication of its position in the quarry. Wheatley (1871) figured it as vase-shaped, and even after more extensive invasive explorations, it retained a fairly symmetrical form (Mercer, 1899). The Ledger Formation has a pronounced dip, and, typically, groundwater solution features develop preferentially along the dip planes between beds. That the Port Kennedy sinkhole was encountered in symmetrical cross-section may be an indication that it was met along the strike of the Ledger Formation. Wheatley's (1871, p. 235) description of the first encounter supports this view, that it was met ". . . in cutting [horizontally] through the floor of a small cave, nearly the whole of the walls of which cave had been removed . . . ." Since the walls adjacent to the sinkhole had been nearly removed, and since the cave's cross-section then was symmetrical, one can conclude that the sinkhole was either completely symmetrical, or, if asymmetrical, opened down dip, away from the viewer. Contrarily, Mercer's (1899, fig. 1) diagram of the deposit shows the filled-in solution feature as perpendicular to the dip of the limestone, but, as we have noted, this two-dimensional view may be a generalized composite drawing that does not show the true dip angle at the site.

Mercer (1899, p. 443) provides additional information on the dimensions and position of the sinkhole:

> They were twelve feet deeper than Mr. Wheatley had been at the previous time, in a gallery filled up with stratified rubbish whose roof, if it had been a roof, had been blasted away, whose bottom had never been reached and whose horizontal extent no one can guess. They were not standing in the darkness under a rock arch, but in the open quarry, forty-five feet below the original surface of the hill, at the very bottom of the quarried area, and below its water level, so deep that the drainage hole close by had to be pumped out day and night to keep the floor dry. A great mass of red talus, unfortunately dumped exactly upon the deposit, overhung them ready to fall as the digging went on.

Without further information on the subsurface extent of the quarry pit, now filled in, we conclude (on stratigraphic and geomorphic data) only that the remains of the sinkhole are probably somewhere on the east to southeast side of the pit. Its precise location will have to be determined if there ever again is an attempt to access the unexcavated remains of the fossil deposit.

The site now is filled in to the level of County Line Road and the old rail spur. We do not know the depth of the fill; it could be about 50 feet because the sinkhole was measured as 40 feet deep in 1870, and at least 12 additional feet were exposed when the site was re-collected in 1894-1896. The "original surface of the hill" noted by Mercer is not a useful reference point because the hill in this area slopes toward the Schuylkill River tributary. Since the rail line is shown consistently in one place in all available maps, we make the assumption that it defined the southeasterly wall of the quarry, and that its grade remained unaltered since the time it was built. Since the road and railbed both follow the trend of an already low topographic tributary of the nearby Schuylkill River, it is unlikely that they would have been lowered much more. If the sinkhole was uncovered in the easterly wall, the wall at that time would have had overburden on it that is no longer present. That overburden, noted in Mercer's (1899) detailed description of the locale, would have risen well above the road level, but it easily could have been removed before quarry operations ceased. Since the depth of the sinkhole was measured from the stratigraphic unconformity, which would have been above road level, some unknown footage may have to be subtracted from the 50-foot figure cited above. The unconformity, however, is angular, and no precise calculations can be determined from the position of the unconformity.

Today, the flat surface area of the filled-in quarry is overgrown by weeds and is rutted in places. The back (northwesterly) wall, until recently rather well exposed, is known to geologists for the excellent view of the angular unconformity between the Ledger and Stockton formations (see Goodwin, 1964, fig. 106), a stratigraphic contact of a type not often seen well in the eastern United States. Today the back wall is weathered and largely hidden from a distant view by vegetation, and with summer foliage it is all but completely obscured. The unconformity itself is also topographically irregular in the quarry wall, plunging northward as seen in the wall; it nearly reaches the present ground surface on the northern end of the exposure. Rip-up clasts of Ledger limestone are incorporated in the lower unit of the Stockton shale, testifying to some activity of regional erosion when the Stockton beds were deposited here. Solution features in the Ledger on the more southerly part of the back wall include a small solution feature large enough to enter. This "cave," on the side of the quarry opposite from our reconstructed position of the sinkhole, is believed to be unrelated to the sinkhole.

Development of the Sinkhole

The Ledger Formation lies below the soil across most of Valley Forge National Historical Park. Its topographic expression is that of a broad valley with rolling, grassy and brushy hills, typical of a karstic terrain in a temperate climate. Surface streams are nonexistent in the area that is underlain by the Ledger Formation. No solution features presently breach the surface in this area, but surface-breaching sinkholes are transient features that often fill in soon after they are exposed.

The Port Kennedy sinkhole breached the surface in Mid-Pleistocene time, as determined by the fossil content. The lowest deposits are still unknown because, hampered by flooding, workers of 1894-1896 were unable to excavate to the bottom of the deposit. The lowest deposits successfully excavated constituted a black, organic-rich clay. Overlying these beds was a series of concave-up layers of sands and muds; most of the fossils came from this unit. The principal component of the sinkhole, overlying the fossiliferous units, was unfossiliferous infill composed mostly of sediments derived from the Stockton Formation. Thus, we interpret an episode of casual incorporation of fossils, early in the time when the sinkhole was open to the air.

Intuitively, the lifetime of the sinkhole was geologically short. Chemical dissolution and sedimentary infilling are processes that are constantly active, particularly in a temperate climate such as that represented by the fauna and flora of the deposit. Speculation on the number of years the sinkhole remained open to the surface is not worthwhile in the absence of comparative localities in this time and space. Stratigraphic and sedimentologic evidence, as well as taphonomic evidence gleaned from the fossil specimens, indicate that the sinkhole was not filled in catastrophically during the time it acted as a trap.

The filling of the larger, upper portion of the sinkhole by debris of the Stockton Formation, and the relatively thin clay units bearing the organic remains closer to the known bottom of the sinkhole, both suggest that the sediments with organic remains were deposited only after the initial opening of the sinkhole to the surface. Once the sinkhole was filled with Stockton debris, there appears to have been no further communication with the surface. But, without sedimentologic samples of the infilled upper portion of the sinkhole, we will not speculate on whether those sediments were catastrophically or otherwise rapidly deposited. All we know of it is that "The whole of the space above this level [the fossiliferous beds] is filled with the débris of the adjoining Mesozoic red shale, with occasional angular fragments of Auroral limestone, without any trace of organic remains" (Wheatley, 1871, p. 236). This does suggest a fairly rapid closure of the sinkhole, ending its service as a trap for biotic remains.

Deposition and Stratigraphy in the Sinkhole

Early investigators of the Port Kennedy fossils interpreted various degrees of catastrophism in the depositional history of the deposit. They essentially saw the deposit as the result of flood sedimentation in a cave. Glacial floods were the principal mechanism cited. In this way, the diverse fauna and flora could be effectively explained, either as direct deposition during a localized catastrophe (as cited in various forms by the early workers), or as redistribution caused by backwaters of a glacially flooded Delaware River Valley (Heilprin, 1895).

Some fossil specimens from the Port Kennedy sinkhole are still in blocks of matrix, or have some sediments still attached to them. Together with the stratigraphic profile provided by Mercer (1899, fig. 9), we can make some interpretations of the depositional events in the sinkhole.

When the deposit was studied in the late nineteenth century, researchers believed the sediments and fossils to have been catastrophically deposited, the result of a flood. Only in this way could fragmentary, yet untransported, remains be explained. Cope (1871, p. 101) concluded: "No agency is at hand to account for their excavation, comparable in potency and efficiency to the floods supposed to have marked the close of the glacial period . . . ." He added that subsequent submergence of the deposit was indicated. Further testimony for the assumption of sudden flood deposition can be seen in Cope's (1871, p. 93) remark on plant matter associated with a rabbit skull: "One of them had an oval mass of carbonaceous matter in its mouth, probably the remains of its unswallowed vegetable food."

Wheatley (1871, p. 237) had observed no significant transportation of the fossils: "Neither the bones or [*sic*] teeth are rolled or water-worn, but all are sharp and well defined." The sudden violence of deposition could also have been interpreted from the number of unidentifiable bone fragments, as observed by Cope (1871, p. 83): "[There are] Fragments of many long bones, including many condyles . . . , but in the lack of certainty as to their proper reference, [they] are not described." And in another remark on selective preservation of more delicate skeletal elements, Cope (1871, p. 94) commented on a dentition of *Praotherium palatinum* extracted from matrix: "Behind the fourth no trace of tooth or bone could be found on exploring the matrix, though the latter was unbroken . . . ."

Within the sinkhole, two distinct fossiliferous layers were recognized by Wheatley (1871). He reported that all of the plants and coleopterids—as well as most of the smaller vertebrates—came from a black clay he called the "plant bed." All of the larger vertebrates came from a hard, red clay underlying the black clay. Cope (1871, p. 73) quoted Wheatley's description of occurrence, but added exceptions: ". . . two of the specimens referred to *Arvicola sigmodus* came from the red bed, and one from the black; one *Megalonyx wheatleyi*, came from the black bed, the others from the red. Milk teeth of Mastodon occur in the red bed also." Unfortunately, we do not have any large amounts of matrix which are known to be from the 1870 excavations.

Figure 2 (FOLLOWING PAGES). Published diagrams of the Port Kennedy quarry and fossil deposit. **A**, Wheatley's (1871, fig. 2) cross-section of the fossil deposit after its discovery by quarry workers. "Mesozoic shale" is the Stockton Fm., "Auroral limestone" is the Ledger Fm. Note fossiliferous beds near bottom of deposit. Note also the character of the angular unconformity. **B-E**, all from Mercer (1899): **B**, Redrawing of Wheatley's (1871) fig. 2. **C**, Cross-section reconstruction of the deposit, combining Wheatley's (1871) and Mercer's (1899) cross-sections of the deposit as it appeared in 1871 and 1894-1898, respectively. **D**, Cross-section of the fossil deposit and quarry as they appeared in 1894-1898. Note the location of excavations of the controlled 1894-1896 survey, and the position of the parts of the deposit that remain in place today (but buried). **E**, Cross-section showing structure of sediments and fossil remains, indicated by Mercer as "stratification by water." A detailed fold-out cross-section (Mercer, 1899, fig. 9, not reproduced here) included locations of different fossils in the sinkhole debris.

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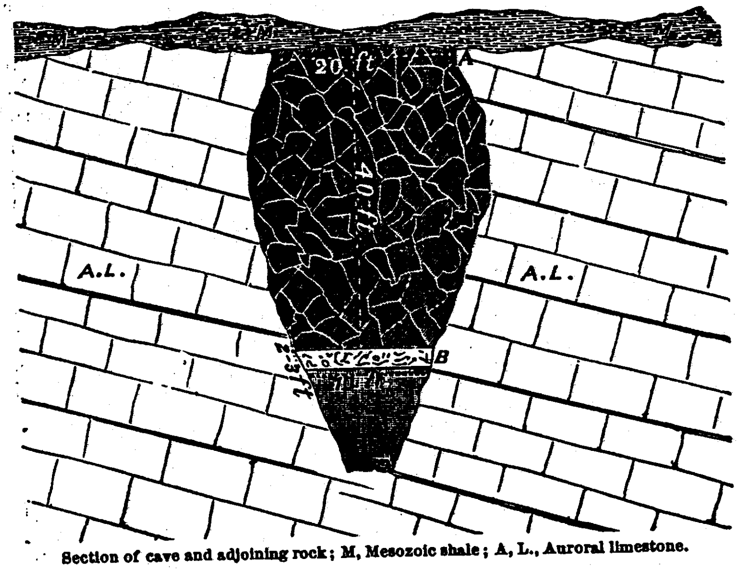


Section of cave and adjoining rock; M, Mesozoic shale; A, L., Auroral limestone.

A

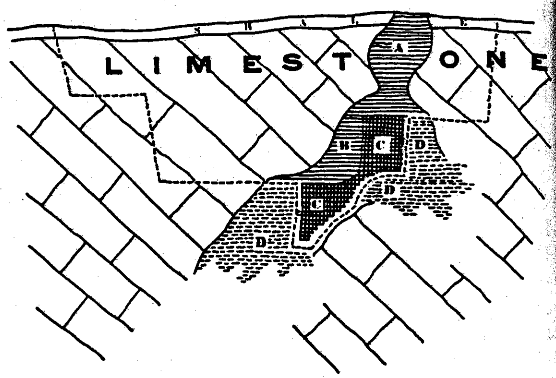


FIG. 11.—THE PORT KENNEDY BONE CAVE.

East and west cross-section of the south end of Erwin's quarry (not drawn to scale for the sake of clearness), showing in *the shaded parts* A, B, C, D the probable original shape, size and relative position of the chasm. *The continuous dotted line* shows the area of rock and debris, and a portion of the original cave at present removed by the blasting and excavation of limestone at the quarry.

***The lined shading at A* shows the probable portion of the contents of the chasm removed by Wheatley in 1871.**

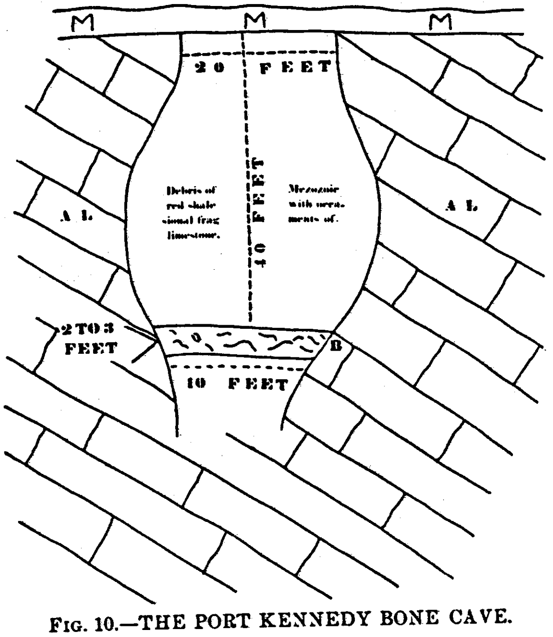
***The lined shading at B* shows the part of the contents of the chasm removed by Dr. Dixon and Mr. Rhoads in 1874.**

***The cross shading at* C C shows that part of the contents of the chasm removed by ourselves in 1894, '95, '96.**

***The dotted shading at* D, D, D shows the position of the contents of the chasm still remaining at the site.**

The lowest continuous dotted line marking the quarry floor is at the level of the neighboring river. The excessive and increasing influx of water at the point marked by the lower letter C, threatening danger to the quarry, prevented further digging in 1896.

C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A L
A L
2 TO 3 FEET
B
10 FEET

FIG. 10.—THE PORT KENNEDY BONE CAVE.

Rough sketch drawn by Wheatley in 1871. His dedescription is as follows:

"*M mesozoic shale; A L auroral limestone. Width at top 20 feet. Below expands to 30 feet. At depth of about 40 feet (B) it is ten feet wide. Black clay B with leaves, stems, etc., 18 in. thick. In red tough clay underneath for six to eight in. in depth, fossils.*

B

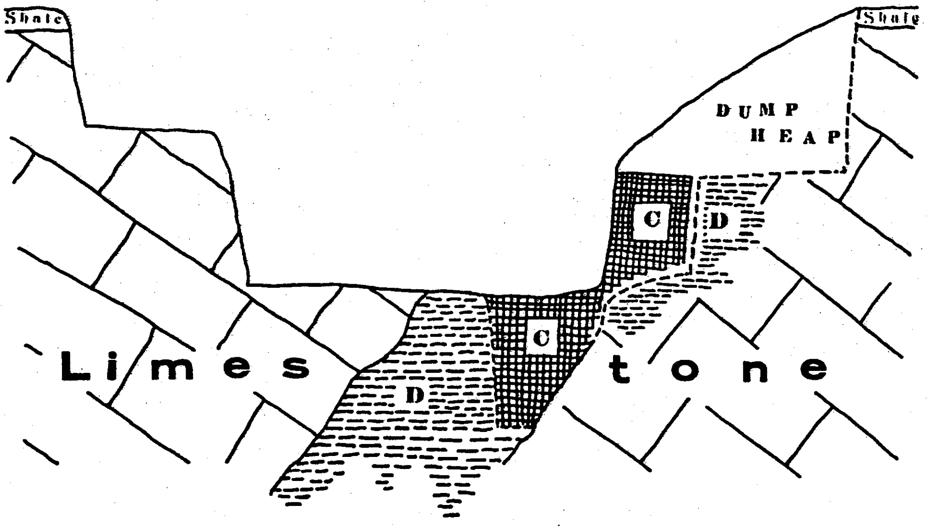


FIG. 1.—THE PORT KENNEDY BONE CAVE.
(Not drawn to scale for the purpose of clearness.)

East and west cross-section of the south end of Erwin's quarry showing in *the shaded parts* C. C. D. D., the position of the bone-bearing fissure with its contents at the time of our first excavation in 1894.

The cross-shaded portion C. C. represents roughly the amount of fossil-bearing debris removed by us in 1894, 1895 and 1896.

The dotted shading D. D. represents the fossil-bearing debris still (1898) remaining in the fissure.

D

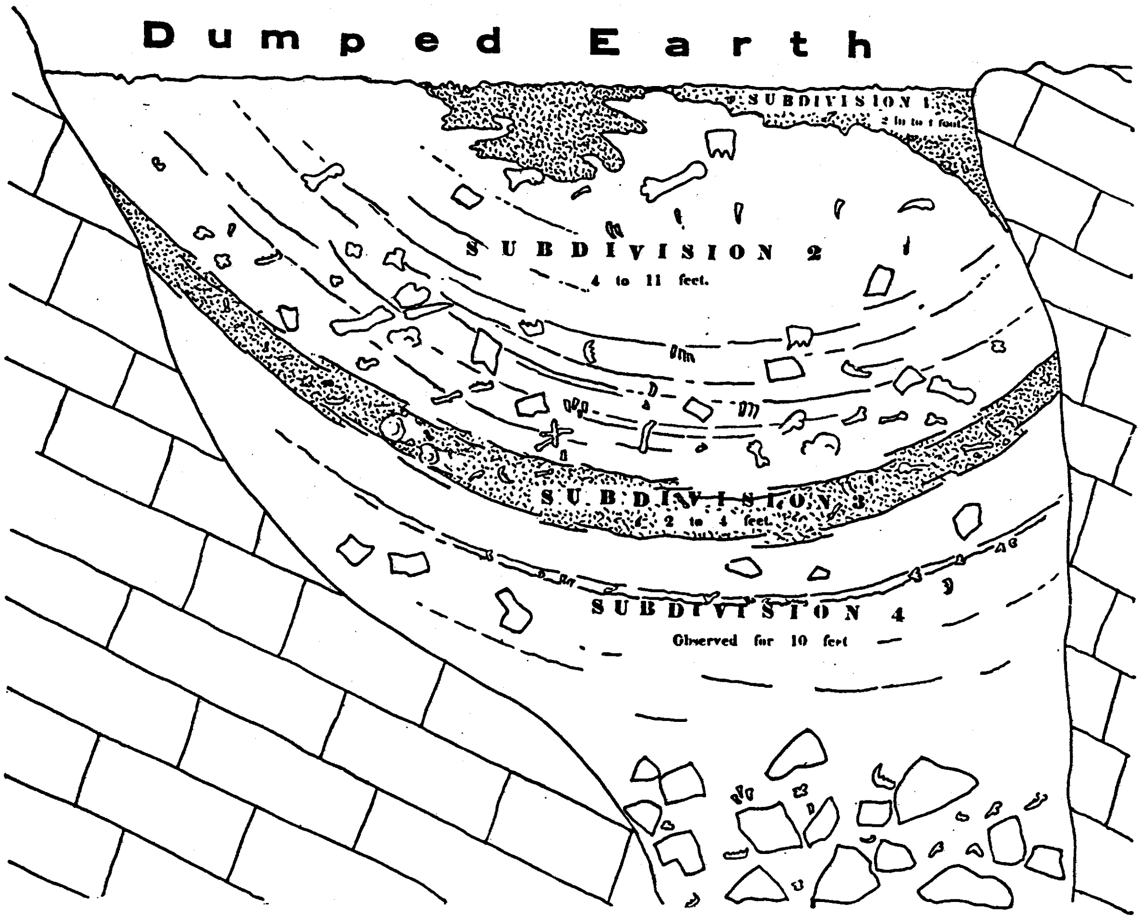


FIG. 5 (Scale 1 in. equals 4 feet).—THE PORT KENNEDY BONE CAVE.

Rough sketch showing the stratification by water. The black subdivisions 1 and 3 alone containing vegetal remains appear identical. Subdivision 1 probably marks the lowest point reached by Wheatley in 1871. The remains of the smallest animals lie in subdivisions 3 or 1, otherwise there is no distinction in fossil contents of the zones of deposition.

E

Mercer's (1899) detailed diagram of the provenance of individual specimens of animals and plants in the sinkhole sediments can be correlated with his coarse, three-dimensional control grid. Many of these coordinates survive, written directly on the specimens. Correlation of specimen data with the original grid is possible, but it will require a lengthy, careful program of repatriation and curation, time or funding for which are not forthcoming at the time this is written. We, however, recognize the potential value for such data, and to this end the collections are being surveyed and organized to prepare for further work. In the meantime, we provide only some additional data on sediment types.

Of the few specimens from Port Kennedy that still contain sediments, the most informative one (ANSP 18990) is one specifically marked (by Mercer?) for preservation as an indication of sedimentation. Mercer (1899) described some of the bone as having a texture uniformly like that of "over-ripe pears." Workers of the Coastal Plain will quickly identify with this description, as many water-saturated strata contain chemically altered bone fossils that exhibit such a consistency, although today many workers refer to the consistency as like "cream cheese." ANSP 18990 is marked, "specimen of bone paste striatum [*sic*] Do not work out"; it is from grid coordinates B,5,6 and remains half in a plaster jacket. In it, large and small (<1 cm to ~5 cm) bone fragments are chaotically arranged. There is no apparent small-scale layering. There is very little actual sandy matrix; instead the block resembles the sloppy slurry of decomposed carbonate rock. A little bit of red matrix is attached to the block. The bone fragments are very friable now; they powder easily on rough, exposed edges. The fragments are both angular and rounded, about evenly distributed between the two types.

Other sediments found attached to specimens are clumps of friable, red, sandy matrix with bone fragments. There are decomposed limey rip-up clasts up to 3-4 cm across; these are irregularly shaped. There is some oxidized banding parallel to exposed surfaces. Some of the sediments are a red clay, dense and smooth, with some granular white (N9) and bluish white (5 B 9/1) clasts incorporated in it. (Color nomenclature is from Rock-Color Chart Committee, n.d.) The general appearance of the red matrix varies, including light brownish gray (5 YR 6/1), pale red purple (5 RP 6/2), grayish red purple (5 RP 4/2), pale reddish brown (10 R 5/4), and dark yellowish orange (10 YR 6/6). Most of the preserved sediment is a medium- to fine-grained sand, with some silt.

Some specimens of matted organic matter contain twig fragments and flakes of mica <1 mm across. The provenance of the mica is probably schist outcrops that occur abundantly in the region (although not in immediate proximity to the locality). Quartz grains <1 mm are also seen.

Leaf remains are found in clay that is mostly brownish gray (5 YR 5/1). Vegetable material with leaf impressions can be found in clayey sediments ranging from medium gray (N5) to dark gray (N3). These are very fine-grained, with few mica flakes <0.1 mm in size. Charcoal and carbonized wood, and what might be compressed dung, range in color from light gray (N7) to black (N1).

The 1870 Collection

The fossils collected by Wheatley and Quick were summarized in a short list by Wheatley (1871, p. 237). There he included mention of coleopterids and plants, numbering ten species each. All of the specimens were collected without precise field documentation. He pointed out that the plant and coleopterid specimens all came from a black clay layer, the "plant bed," while larger vertebrates came from the underlying hard red clay. He tallied 27 species of vertebrates from black and red clay layers. Cope (1871) reported only on the vertebrate remains, providing detailed descriptions of 34 species (11 of them new) based on 72 individuals (Cope, 1871, p. 98).

The 1894-1896 Collection

As Mercer (1899) related, fossils from the Port Kennedy sinkhole were again noticed in spoil piles in 1894 after the quarry floor had been lowered 12 feet. S. N. Rhoads spent some time collecting from these spoils, and from his efforts came a proposal to re-excavate the sinkhole.

Mercer organized the re-excavation with the specific intent of discovering human remains. To establish the precise relationships of the specimens in stratigraphic context, a grid of 1- by 3-foot rectangles was painted on the sediments (Mercer, 1899, fig. 2), providing two-dimensional control on the collecting surface. The third dimension was measured first in three-foot increments into the wall formed by the sinkhole fill material, but concluded with a single six-foot increment. As excavations reached further into the wall of fill, the two-dimensional grid was repainted. This method, described by Mercer (1899) foretells modern collecting techniques, and such control is rather remarkable for the late nineteenth century. It should be pointed out, though, that even though Mercer was carefully documenting the three-dimensional position of fossil remains in the deposit, his primary objective was the precise documention of relationships between fossils in the event that human remains were also recovered; he had hoped to settle "the question of man's antiquity in Eastern North America beyond all doubt" (Mercer, 1899, pp. 271-272). But no human remains were recovered; the deposit predates human occupation of North America.

Many specimens from the controlled re-excavation, including most of the available plant material, still are accompanied by their three-dimensional grid coordinates. Identification of these elements and reestablishing their relative stratigraphic position in the sinkhole fill will be a project of future work.

The Port Kennedy Local Fauna and Flora

The Port Kennedy deposit is best known for its vertebrate remains. However, to gain a perspective of the whole Mid-Pleistocene biotic assemblage, we review the status of specimens and identifications below. Table 1 contains an updated list of the fauna and flora from Port Kennedy. We have included the taxa that we feel are properly identified, based on specimens in the Academy's collections, reliable published accounts, and taxonomic revisions after the original publications.

Invertebrates

Even the first brief description of the Port Kennedy deposit (Wheatley, 1871) mentioned the presence of the remains of beetles (Arthropoda: Insecta: Coleoptera), numbering 10 species. It was not for another five years, however, that the collection was published, by Horn (1876). Horn identified eight genera in the collection made by Wheatley, including seven new species in seven genera while reserving specific identification of four forms placed in three of the genera. This list, and remarks made by Horn (see Table 1), are the only data on the Port Kennedy insects available to us.

Table 1. Fauna and flora of the late Irvingtonian Port Kennedy fossil deposit. The coleopterid remains are cited with all the information known about them (from Horn, 1876, pp. 243-245; specimens missing); identifications are Horn's. Common names for animals and plants are listed in the right-hand column; those for the coleopterids pertain to generic levels since the species are extinct and have no common names.

Kingdom Animalia

Phylum ARTHROPODA	
Class Insecta	
Order Coleoptera	
Family Carabidae	
Cychrus wheatleyi Horn	ground beetles
"Flattened thorax" and "left elytron"	
Cychrus sp. (minor form)	
"Two fragmentary elytra"	
Pterostichus sp.	woodland ground beetles
"Fragments of two elytra"	
Pterostichus? sp.	
"The greater portion of two elytra with the basal and apical ends wanting"	
Cymindis aurora Horn	colorful foliage ground beetles
Two elytra	
Chlaenius punctulatus Horn	vivid metallic ground beetles
One elytron	
Dicaelus alutaceus Horn	notch-mouthed ground beetles
"Two elytra much flattened, retaining their proper position in relation to each other"	
Dicaelus sp.	
"An impression of the greater part of both elytra and a very small fragment of one elytron"	
Family Scarabidae	
Choeridium? [= *Ateuchus*] *ebeninum* Horn	dung beetles
"The greater portion of the thorax, the two elyra in a fair state of preservation and a portion of the abdominal segments"	
Phanaeus antiquum Horn	dung beetles
"Elytra with feeble striae." ". . . the remains consist of an impression with a small portion of the substance of both elytra in position, slightly separated at base by pressure so that a deciptive appearance of an elongate scutellum is presented; also the impression of the abdominal segments with a small portion of chitinous substance." "There is also the substance remaining of the greater portion of an elytron."	
Aphodius precursor Horn	dung beetles
"Elytra" [number not indicated]	
Phylum CHORDATA	
Class Reptilia	
Order Testudines	
Family Emydidae	
Terrepene carolina (Linné)	box turtle
Clemmys insculpta (LeConte)	wood turtle
Emydoidea blandingii (Holbrook)	Blanding's turtle
Family Testudinidae	
Cf. *Geochelone* sp.	tortoise
Order Squamata	
Family Colubridae	
Coluber sp. (or *Masticophis* sp.)	racer (or whipsnake)
Class Aves	
Order Galliformes	
Family Phasianidae	
Subfamily Meleagrinae	
Meleagrinae, gen. undet.	turkey
Class Mammalia	
Order Insectivora	
Family Soricidae	
Blarina brevicauda (Say)	short-tailed shrew
Order Edentata	
Family Megalonychidae	
Megalonyx wheatleyi Cope	Wheatley's ground sloth

[cont'd]

Order Rodentia	
Family Sciuridae	
Sciurus calycinus Cope	squirrel
Marmota cf. *monax* (Linné)	groundhog
Family Erethrizontidae	
Erethizon dorsatum (Linné)	porcupine
Family Castoridae	
Castor canadensis Kuhl	beaver
Family Cricetidae	
Ondatra hiatidens (Cope)	Cope's muskrat
Neofiber diluvianus (Cope)	Diluvian water rat
Arvicolinae, gen. undet.	voles
Family Dipodidae	
Zapus hudsonicus Zimmermann	meadow jumping mouse
Order Lagomorpha	
Family Leporidae	
Sylvilagus floridanus (Allen)	Eastern cottontail
Family Ochotonidae	
Ochotona palatina (Cope)	pika
Order Carnivora	
Family Mustelidae	
Lutra canadensis (Schreber)	river otter
Brachyprotoma obtusata (Cope)	short-faced skunk
Osmotherium spelaeum Cope	Port Kennedy skunk
Gulo schlosseri (Linné)	Schlosser's wolverine
Taxidea taxus (Schreber)	badger
Mustela diluviana (Cope)	Diluvian fisher
Family Ursidae	
Arctodus pristinus Leidy	lesser short-faced bear
Ursus americanus Pallas	black bear
Family Canidae	
Canis priscolatrans Cope	wolf coyote
Canis cf. *armbrusteri* Gidley	Armbruster's wolf
Urocyon cinereoargenteus (Schreber)	gray fox
Family Felidae	
Smilodon gracilis Cope	gracile sabertooth
Felis yagouaroundi Lecepede	jaguarundi
Lynx rufus (Schreber)	bobcat
Miracinonyx inexpectata (Cope)	North American cheetah-like cat
Panthera onca (Linné)	jaguar
Order Perissodactyla	
Family Equidae	
Equus pectinatus Cope	giant horse
Family Tapiridae	
Tapirus haysii Leidy	Hays' tapir
Order Artiodactyla	
Family Cervidae	
Odocoileus virginianus Zimmermann	white-tailed deer
Teleopternus orientalis Cope	large cervid?
Family Tayassuidae	
Mylohyus nasutus (Leidy)	long-nosed peccary
Order Proboscidea	
Family Mammutidae	
Mammut americanum Kerr	American mastodont

Kingdom Plantae

Fagaceae	
Fagus grandifolia Ehrh.	American beech
[Identified as *F. ferruginea* by early workers at Port Kennedy]	
Quercus palustris Muenchh.	pin oak
Quercus alba L.	white oak
Quercus macrocarpa Michx.	bur oak
Betulaceae	
Corylus americana Marsh.	American hazel, American filbert

Pinaceae	
Pinus rigida Mill.	pitch pine
Rosaceae	
Prunus sp.	
Crataegus crus-galli L. or *C. chrysocarpa* Ashe	cocksupr hawthorn or fireberry hawthorn
[Identified as *C. crusgalli*? by early workers at Port Kennedy]	
Crataegus sp.	
Juglandaceae	
Carya ovata (Mill.) K. Koch	shagbark hickory
Carya glabra (Mill.) Sweet	pignut hickory
[Identified as *C. porcina* by early workers at Port Kennedy]	
Carya tomentosa Nutt.	mockernut hickory
[Identified as *C. alba* (L.) Britt. by early workers at Port Kennedy]	
Vitaceae	
Parthenocissus quinquefolia (L.) Planch.	Virginia creeper
[Identified as *Ampelopsis quinquefolia* by early workers at Port Kennedy]	
Sphagnaceae	
Sphagnum sp.	sphagnum moss

Mercer (1899, p. 281) also remarked that "a single wing of one unidentified individual" was found in the 1894-1985 collections, but he otherwise simply transcribed the list of Horn's identifications. A search of the Invertebrate Paleontology and Entomology collections in the Academy of Natural Sciences has not relocated these specimens.

Horn (1876) acknowledged Cope's (1871) assignment of "Post-Pliocene" age to the Port Kennedy fossils. Horn, like Cope (1871), took the opportunity to make some remarks regarding evolution and paleobiogeography generally, making observations on North American distributions of coleopterids of the Recent and of "preceding geological periods." And even though Horn encouraged restraint in the naming of new coleopterid species based on fragmentary remains, he believed some of the fragments from Port Kennedy to be distinct enough from Recent species to warrant naming new species. Horn's descriptions show attention to detail, provide comparisons to Recent species, and thus outwardly seem to show conservatism. Unfortunately, without access to these specimens today, we can only recite Horn's identifications (Table 1). We suppose that Horn's generic identifications are accurate for genera as understood in 1876, but some of them have undergone revision, particularly subdivision, since then.

We use information on the insect remains to support interpretations of taphonomy. Horn (1876) was careful to note the condition of some of the coleopterid specimens he described, and it is this information we partly rely upon in drawing our conclusions.

It is, perhaps, curious that no mention has been made of molluscan remains beyond Mercer's (1899, p. 281) remark that none were found. It is likely that terrestrial snails, particularly, would have lived in the area of the sinkhole—either indigenous regional populations or opportunistic species that feast on decaying animal or plant remains. (Interestingly, two of the genera of beetles described by Horn, 1876—*Cychrus* and *Dicaelus*—are especially known to be snail-eaters [Arnett, 1968; White, 1983], although they of course do feed on other material.) If at any time the sinkhole contained standing water, we also might expect some colonization by aquatic mollusks like the proliferate Physidae. We assume that the molluscan specimens did not preserve in the sinkhole deposits; their calcium carbonate shells were dissolved by the action of dilute carbonic acid in the groundwater of the karstic terrain. An examination of the remaining pieces of matrix for external molds of snails, fragmentary or otherwise, showed nothing to us.

Lastly, even though interpretations of the paleoenvironment of the Port Kennedy area during the time the sinkhole trap was open are well documented by the megafauna and plants, we note here that the insect identifications can assist to some degree in corroborating these interpretations. The carabid genera are known by modern distributions to be woodland and grassland beetles, some prefering moist vegetational detritus and wet ground, and all of them favoring warm to temperate climate. The scarabids are dung beetles, mostly preferring humus or the dung of larger animals.

Vertebrates

The culmination of the early work on the vertebrate fauna from Port Kennedy Cave was Edward Drinker Cope's "Vertebrate remains from Port Kennedy bone deposit" (Cope, 1899). This paper was published posthumously from a manuscript prepared by Cope during the last year of his life. Edward Nolan, writing in the forword to the paper, states that it was thought best to publish the manuscript just as it was left by the author and without revision. In Nolan's words, the paper "possessed a melancholy interest from the fact that it is the last work of the distinguished paleontologist. Its preparation, which was continued during the intense agony of his last illness, furnishes a striking illustration of his indomitable self-will and devotion to the cause of science."

Cope (1899) discussed four taxa of reptiles and 44 mammals from Port Kennedy. Many of these were new species that Cope named in the 1899 paper or in his earlier papers on the deposit (Cope 1871, 1895, 1896). Mercer (1899) described the process of excavation and other particulars about the site, and he included floral and faunal lists that incorporated reports from all previous papers. He listed five reptiles, two birds, 51 mammals, 12 insects, and 13 plants from the site. Hay (1923) also presented a faunal list for Port Kennedy based upon Cope's series of papers, as well as the other papers on Port Kennedy by Wheatley (1871) and Mercer (1899). Hay's composite list included one amphibian, four reptiles, one bird, and 54 mammals. Like Mercer's list, Hay's is misleading because many of the taxa included were only provisionally mentioned by the authors. More recent studies have reexamined material of specific vertebrate taxa from the site (e.g., Hall, 1936, on mustelids; Hibbard, 1955, on microtine rodents; Van Valkenburgh et al., 1990, on the cheetah-like cat, *Miracinonyx*) rather than dealing with the fauna as a whole.

REPTILIA

Testudines

Cope (1899) reported three kinds of turtles from Port Kennedy. Two of these (*Toxaspis anguillulatus* and *Clemmys percrassa*) were new taxa. The third taxon was the wood turtle, *Clemmys insculpta* LeConte. Hay (1908) reviewed this material and commented that *T. anguillulatus* was indistinguishable from *Terrepene eurypygia* (Cope). He went on to say that *T. eurypygia* is closely related to, or may be the same as *Terrepene carolina* Linné. Milstead (1965) sees no reason to recognize *T. eurypygia* as a species distinct from *T. carolina*. With respect to *Clemmys percrassa*, Hay only stated that it probably belonged in the genus *Testudo* rather than *Clemmys*. He also mentioned that the remains of *Clemmys insculpta* from Port Kennedy were very fragmentary and that there was a possibility that they belonged to some related but undescribed species.

Reexamination of the turtle specimens by one of us (D.C.P.) in 1992 revealed several items of interest; first, the presence of an unrecognized taxon from the site. ANSP 161, a plastron, belongs to Blanding's turtle, *Emydoidea blandingii* (Holbrook) (Pl. 1, fig. a). This interpretation of the Port Kennedy specimen was made upon comparing it to the holotype of *E. blandingii*, a Recent specimen (ANSP 26123, Department of Herpetology). Second, the type of *Clemmys percrassa* (ANSP 152) is reinterpreted as belonging to the tortoise *Geochelone* (Parris, in prep.). And third, the presence of *Clemmys insculpta* and *Terrepene carolina* is confirmed in the Port Kennedy fauna.

Serpentes

Cope (1899) described only one type of snake from the site, *Zamenis acuminatus* Cope. In a footnote in Cope (1899) the editor, Edward Nolan, indicated that the specimen that Cope referred to in the text, presumably the type for this taxon, could not be located. There are a number of trunk vertebrae of a snake present in the collection today (Pl. 1, fig. b). Hay (1923) referred *Z. acuminatus* to the genus *Coluber*. Gilmore (1938) diagnosed the Port Kennedy snake as *Coluber* sp., and Holman (1981) pointed out that with vertebral remains from North American Pleistocene localities one generally cannot distinguish between the genera *Coluber* and *Masticophis*. The vertebrae present in the collection are clearly one of these genera, and comparing the location of the Port Kennedy deposit to modern distributional records for these snakes it would more likely be *Coluber*.

AVES

Galliformes

Wheatley (1871) reported a single specimen of turkey from Port Kennedy, identified there only as "turkey." Mercer (1899) included *Meleagris altus* Marsh on his faunal list for the site. Others have cited this record, and Steadman (1980) indicated that *M. altus* is a junior synonym of *Meleagris gallopavo* Linné. Steadman (1980) also pointed out that the single carpometacarpus he examined from Port Kennedy (probably not the same specimen mentioned by Wheatley, 1871), resembled *Meleagris* in size but differed from that genus in other features. Other bird specimens that have recently been recognized in the collection include the proximal end of a coracoid, distal end of a humerus, and the distal end of an ulna; these also may belong to a turkey.

MAMMALIA

Insectivora

Shrews are known only from one specimen at Port Kennedy. Cope (1899) described *Blarina simplicidens* from the single jaw in matrix. Hibbard (1957) reduced *B. simplicidens* to subspecific status of *Blarina brevicauda*. Jones et al. (1984) recognized *B. simplicidens* as a junior synonym of *B. brevicauda talpoides*.

Edentata

Sloth remains occur in great numbers from Port Kennedy. Cope recognized six species from the site; only one is currently considered valid. The presence of *Mylodon harlani* was based on a single ungual phalanx that is now grouped with the rest of the sloth remains. Subsequent workers have not mentioned the bone in question, and this taxon is not considered to have been accurately identified.

In 1871, Cope named four species of the genus *Megalonyx* from the site; they were *M. loxodon* (from a single tooth), *M. sphenodon*, *M. tortulus*, and *M. wheatleyi*. In his 1899 paper, Cope referred *M. sphenodon* to *M. wheatleyi* and added another taxon, *M. scalper*. A study of megalonychid sloths by Hirschfeld and Webb (1968), which took individual variability into account, concluded that all of the Port Kennedy sloth material is a single species, thus Cope's taxa are junior synonyms of *Megalonyx wheatleyi*. The specimens of *M. wheatleyi* from Port Kennedy make up one of the largest samples of this taxon known from a single site (McDonald, 1977).

The syntypic suite of *Megalonyx wheatleyi*, "fourteen canine and sixteen molar teeth" (Cope, 1871, p. 75) (= caniniforms and molariforms; cf. McDonald, 1977), may be among 35 caniniform and 70 molariform teeth of the species under many ANSP catalogue numbers. Unfortunately, Cope's original material is not specially marked, and future workers may wish to investigate the necessity of designating a neotype.

Lagomorpha

Cope (1871) mentioned two lagomorphs from Port Kennedy. These were *Praotherium palatinus* Cope and *Lepus sylvaticus* Bachman. Cope (1899) reassigned the first to *Lagomys palatinus*. Hay (1923) recorded this taxon as *Ochotona palatina*, the extant genus of pika in North America. Cope (1871) figured the unique specimen of the upper dentition (AMNH 8574). Kurtén & Anderson (1980) stated, "A form described by Cope (1871) from Port Kennedy Cave under the name *Praotherium palatinum* may be an ochotonid, but its status is uncertain."

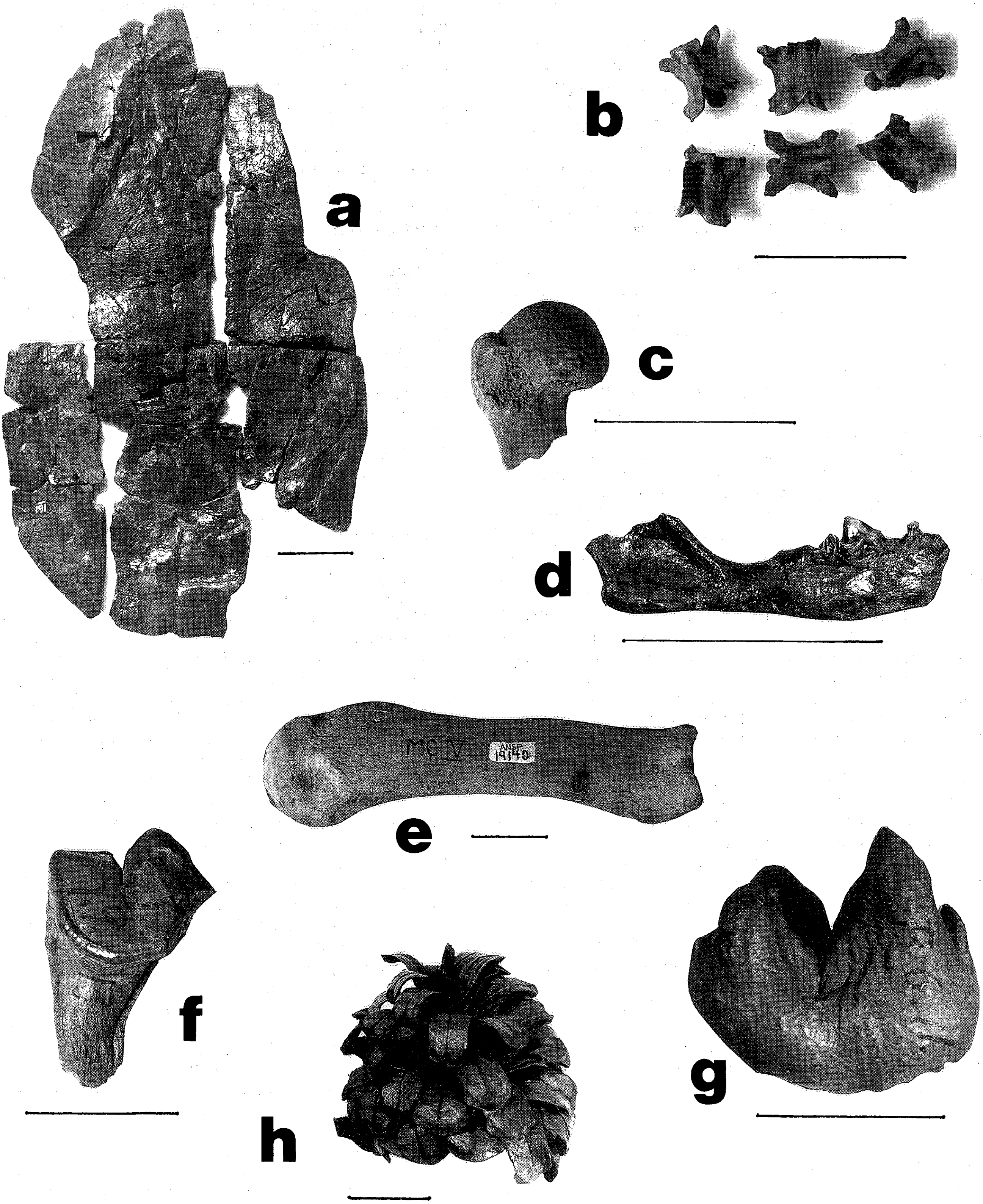
Cope mentioned examining a large number of individuals of *Lepus sylvaticus*. Hay (1923) indicated that this taxon is a junior synonym of *Sylvilagus floridanus* (Allen), which Kurtén & Anderson (1980) also recognized from the site. Additionally, the late J. E. Guilday left notes found with the Academy's specimens stating that the Port Kennedy rabbits belong to the genus *Sylvilagus*.

Rodentia

Cope first mentioned the presence of beaver at Port Kennedy in his 1895 paper. A single well-preserved mandible and three isolated teeth were noted in 1899 as *Castor fiber* Linné. This taxon has been reidentified as the North American beaver, *Castor canadensis* Kuhl.

The porcupine from Port Kennedy was first described by Cope (1871) as *Erethizon cloacinum*. In 1899 Cope referred only to *Erethizon dorsatum* (Linné). White (1970) indicated that the taxon at Port Kennedy is an indeterminate species of

Plate 1



Port Kennedy fossil specimens; scale bars = 2 cm. **a,** Partial plastron of emydid turtle, *Emydoidea blandingii* (ANSP 161). **b,** Trunk vertebra of colubrid snake (ANSP 18961). **c,** Proximal humerus of *Marmota* cf. *monax* (ANSP 19125). **d,** Rediscovered holotype of *Brachyprotoma obtusata* (Cope), a right mandible with alveolus of canine, p_2, p_4, and broken M_1 (ANSP 18906). **e,** undetermined metapodial of *Tapirus haysii* (ANSP 19140). **f,** Right p^4 of *Canis* cf. *armbrusteri* (ANSP 58.1). **g,** Unworn right dp_2 of *Mammut americanum* (ANSP 18832). **h,** Intact cone of pitch pine, *Pinus rigida* (ANSP Paleobotany 2342).

the genus *Coendou*, based on the age, but Frazier (1981) has shown that the Port Kennedy specimens are clearly *Erethizon dorsatum*, the extant porcupine.

The muskrat from Port Kennedy, *Ondatra hiatidens* (Cope, 1871), is unique to this site. It was described by Cope under a number of different names: *Arvicola* (*Anaptogonia*) *hiatidens* Cope, 1871; *Microtus* (*Anaptogonia*) *hiatidens* Cope, 1896; *Anaptogonia cloacina* Cope, 1896; *Anaptogonia hiatidens* Cope, 1899; and *Sycium cloacinum* Cope, 1899. Hibbard (1955) listed all of these names as junior synonyms of *Ondatra hiatidens* (Cope). Repenning & Grady (1988, p. 18) note, however, that it is difficult to make species determinations within *Ondatra* with only small samples. The Port Kennedy specimens number just five.

Cope (1899) recognized *Microtus diluvianus* Cope, 1896 and *Schistodelta sulcata* Cope, 1899. These two microtine taxa are referred to *Neofiber diluvianus* (Cope) by Hibbard (1955). This water rat is also unique to the Port Kennedy deposit.

Among the rodents, the voles are perhaps the most confused taxonomically and the most difficult to identify. Cope (1871) described *Arvicola* (*Isodelta*) *speothen*, *Arvicola tetradelta*, *Arvicola didelta*, *Arvicola sigmodus*, and *Arvicola involuta*. In 1899, he revised his taxonomy and described *Microtus involutus*, *Microtus dideltus*, and *Microtus speothen*. Hibbard (1955) recognized *Microtus speothen*, but called the other two taxa *Pedomys* or *Pitymys dideltus* and *Pedomys* or *Pitymys involutus*. Van der Meulen (1978) considered *Pitymys involutus* to be a *nomen dubium*. Kurtén & Anderson (1980) concurred and also considered the *speothen* and *dideltus* species to be *nomina dubia*. Martin (1987) also concurred with this assesment of Cope's taxa. Kurtén & Anderson (1980) listed all of Cope's names under *Microtus guildayi* Van Der Meulen, presumably because of their age. We have found in ANSP collections additional well preserved dentitions, but deferring to workers who have expertise in such identifications we feel it prudent to refer the specimens only to the subfamily Arvicolinae (*sensu* Repenning & Grady, 1988).

A squirrel, *Sciurus calycinus*, was described by Cope (1871) from two partial lower jaws (AMNH 8577). Cope mentioned that in size this taxon compared well with *Sciurus hudsonicus*, but that it differed in details of the cheek teeth. *Sciurus hudsonius* has been listed as a junior synonym of both *Tamiasciurus hudsonicus*, the red squirrel, and *Glaucomys sabrinus*, the flying squirrel. We have not seen the specimen to make a redetermination.

We have included in our faunal list *Zapus hudsonius*, reported by Cope (1899) based on a single partial mandible with one cheek tooth. The specimen has not been located.

A single specimen of the groundhog, *Marmota* cf. *monax*, has been found in the Academy's collection (ANSP 19125). The specimen is the proximal end of a humerus (Pl. 1, fig. c) and was first identified as *Marmota* sp. by J. E. Guilday in 1982 (*cf.* note with specimen). This is a new record for the site.

Carnivora

According to Kurtén & Anderson (1980), Port Kennedy has produced the earliest record of the black bear, *Ursus americanus*, which was first noted by Cope (1895).

The larger and more abundant ursid at the site is *Arctodus pristinus* Leidy. The sample size from Port Kennedy is the largest known of this taxon (Kurtén, 1967). In 1871, Cope referred to *Arctotherium pristinum*, and Wheatley to *Ursus pristinus*, as occurring in the Port Kennedy deposit. In 1896 and 1899, Cope reclassified the specimens as *Ursus haplodon* Cope. Hay (1923) included *Arctotherium haplodon* in his faunal list for Port Kennedy. Kurtén (1967) indicated that *Arctodus pristinus* is the senior synonym for all of these names.

Cope (1895, 1899) mentioned the presence of the gray fox at Port Kennedy, referring to it as *Vulpes cinereoargentatus* Schreber. This taxon has been reassigned to the genus *Urocyon*. Kurtén & Anderson (1980) point out that this is an early record of the gray fox.

Another fox, which Cope named in 1899, is *Vulpes latidentatus*. This species has not been recognized in subsequent literature; it is probably a junior synonym of *Urocyon cinereoargenteus*.

Cope (1899) described a new canid based on a few teeth from Port Kennedy. This species, *Canis priscolatrans*, was reduced by Nowak (1979) to a subspecies of the Recent species, *C. rufus*, the red wolf. According to Nowak (1979, p. 90) the Port Kennedy teeth fall well within the range of variation of those of *C. rufus*. Kurtén & Anderson (1980) maintained that *C. priscolatrans* is a distinct species because of the temporal gap between the Port Kennedy specimens and *C. rufus*. Anderson (1984), however, listed *C. rufus* from Port Kennedy. Savage & Russell (1983) included *C. priscolatrans* and not *C. rufus* in their list of Irvingtonian mammals.

Another canid appears to be present at Port Kennedy. Several upper carnassials as well as postcranial bones of a species quite a bit larger than *Canis priscolatrans* are in the Academy's collection. Cope (1899) mentioned some of these specimens, but he did not elaborate on their affinities. Nowak (1979) considered this to be *Canis armbrusteri* Gidley. We have compared the length of the upper carnassials to published data on *Canis armbrusteri* Gidley from Cumberland Cave, Maryland (Gidley & Gazin, 1938). The Port Kennedy specimens are only slightly smaller (Pl. 1, fig. f).

Mustelids are quite common from Port Kennedy, especially the skunk *Osmotherium spelaeum* Cope, 1899, which is known only from that site. Initially, the only skunk that Cope (1895) mentioned from the site was *Mephitis mephitica* Linné. In later publications Cope omitted *M. mephitica* from discussions but erected six new species (Cope, 1896) which were described more fully in the posthumous work (Cope, 1899): *Mephitis orthostichus*, *Mephitis fossidens*, *Mephitis leptops*, *Pelycictis lobulatus*, *Osmotherium spelaeum*, and *Mephitis obtusatus*. Of these species, Hall (1936) synonymized all but *M. obtusatus* with *Osmotherium spelaeum*. Kurtén & Anderson (1980) recognized Hall's taxonomy but indicated that the genus *Osmotherium* may not be distinct from *Mephitis*.

The single specimen of *Mephitis obtusata* Cope was reassigned by Hall (1936) to *Brachyprotoma*. Hall (1936, p. 47) noted that *Brachyprotoma* was known from four deposits, and commented that "All materials reported upon from these places have been examined by the present writer, except those from Port Kennedy which are now lost." Edward Nolan, the editor of Cope's (1899) posthumous paper, noted that none of the specimens labelled by Cope bear the name *Mephitis obtusata*. Cope, however, did supply measurements of the specimen. An uncataloged specimen (now ANSP 18906) was located in the Academy's systematic collection in 1992; it matches the measurements given by Cope for the type, and a label written in Cope's hand, reading *Mephitis obtusata*, accompanies the specimen. We believe this is the type specimen of *M. obtusata* (Pl. 1, fig. d).

Other, more rare, mustelids from Port Kennedy include badger, wolverine, otter, and fisher. Cope (1899) mentioned only one specimen of *Taxidea americana* Bodd. Hall (1936) listed this taxon as a junior synonym of the extant badger, *Taxidea taxus* (Schreber).

Cope (1899) listed *Gulo luscus* Linné from Port Kennedy. Hall (1936) referred this taxon to *Gulo gidleyi*, and Kurtén & Rausch (1959) listed these as junior synonyms of *Gulo gulo* (Linné), the extant wolverine. Kurtén & Anderson (1980) and Anderson (1984) listed *Gulo schlosseri* Kormos as the Irvingtonian-age wolverine in North America, stating that it is ancestral to *Gulo gulo*. We refer the Port Kennedy material to *G. schlosseri*. Kurtén & Anderson (1980) indicated that after the record of wolverine in the Irvingtonian Port Kennedy and Cumberland faunas, they are absent from the North American Pleistocene record until the Wisconsinan.

Cope (1896) mentioned a new species of otter, *Lutra rhoadsii*, that he described more fully in 1899 from a single specimen. Pohle (1920) regarded *L. rhoadsii* as a junior synonym of *L. canadensis* (Schreber). Hall (1936) agreed with this synonymy, and Kurtén & Anderson (1980) indicated that Port Kennedy and Cumberland Cave are the earliest records of the American river otter.

Cope (1899) described a new mustelid from Port Kennedy as *Mustela diluviana*, the diluvian fisher. Hall (1936) reassigned this species to the genus *Martes*. This species is recognized only from Port Kennedy.

The cats from Port Kennedy have been of great interest to researchers in recent years. Cope (1880) named *Smilodon gracilis* based on a specimen from Port Kennedy. In 1895, Cope mentioned *Uncia mercerii*, which he later (Cope, 1899) described as *Smilodon mercerii*. Also in 1899, Cope reassigned *S. gracilis* to *Machaerodus*. Thus Cope recognized two taxa of sabertooth cats from Port Kennedy. Kurtén & Anderson (1980) recognized the priority of *Smilodon gracilis* and also proposed the synonymy of *S. mercerii* with *S. gracilis*. Berta (1987) has concurred with this nomenclature.

Cope (1895, 1899) recognized a single specimen of a small cat that he referred to as *Felis eyra* Desmarest. Kurtén & Anderson (1980) referred this specimen to *Felis yagouaroundi* Lecepede, stating, "An early Irvingtonian form at Port Kennedy (referred to *F. eyra* by Cope, 1899) may represent an earlier invasion of jaguarundi or a related form."

Lynx rufus was mentioned by Cope (1895) as occuring in the Port Kennedy deposit. But in 1899, he described *L. calcaratus* for all of the bobcat specimens from the site. Kurtén & Anderson (1980) listed *L. calcaratus* as a junior synonym of *L. rufus*.

Crocuta inexpectata was described by from Port Kennedy by Cope (1895). This species was later assigned by Cope (1899) as *Uncia inexpectata*. Simpson (1941) reassigned the taxon to *Felis*. Savage (1960) felt that *F. inexpectata* was a *nomen dubium* because it was based on insufficient material, so he referred the material to a new taxon, *Felis studeri*. Kurtén & Anderson (1980) reassigned this taxon to *Acinonyx*. Since that time, Van Valkenburgh et al. (1990) have reported that specimens from Hamilton Cave, West Virginia, have corroborated the description of the material from Port Kennedy, and Cope's taxon is indeed recognizable. Van Valkenburgh et al. (1990) have recognized *Miracinonyx inexpectata* (Cope) for the cheetah-like cat from Port Kennedy.

Although the early reports from Port Kennedy do not mention jaguar (*Panthera onca*), Simpson (1941), Kurtén (1976), Berta (1987) and K. Seymour (pers. commun., 1992) all cite its presence there.

Artiodactyla

Cope (1896, 1899) described a deer he called *Cariacus laevicornis* from Port Kennedy. Hay (1923) included *Odocoileus laevicornis* and *O. virginianus*? in his faunal list as occuring at this site. Kurtén & Anderson (1980) mentioned only *O. virginianus* from Port Kennedy.

Cope (1899) described another artiodactyl from a few teeth. He called it *Teleopternus orientalis* and stated that it was about the size of an elk. He was unsure whether it was a cervid or a camelid, but placed it provisionally in the Camelidae. Hay (1923) stated that in many respects the teeth resemble those of the Cervidae. The taxon has not been recognized in subsequent literature that we have seen, hence the taxonomic affinities of this species are still unclear.

Three peccaries were described from Port Kennedy by Cope (1899). These were *Mylohyus nasutus* (Leidy), *Mylohyus pennsylvanicus* Leidy, and a new taxon, *Mylohyus tetragonus* Cope. Kurtén & Anderson (1980) recognized only *Mylohyus nasutus*, citing the other taxa as junior synonyms.

Perissodactyla

Specimens of a large horse at Port Kennedy were referred by Cope (1895) to *Equus major* Dekay and *E. fraternus* Leidy. In 1899, Cope discussed only *E. fraternus* and introduced the subspecies *E. f. pectinatus*. Hay (1923) and Kurtén & Anderson (1980) recognized *E. pectinatus* as a full species. Savage & Russell (1983) have not included *E. pectinatus* in their composite list of North American Irvingtonian horses, but they do include the closely related form, *E. giganteus* Gidley.

A large tapir is quite common at Port Kennedy. Cope (1871) first cited *Tapirus americanus* and *T. haysii* Leidy, but in 1899 he listed only *T. haysii*. Simpson (1945) stated that the type specimen of *Tapirus haysii* is "essentially indeterminate and that the species to which it belongs, and consequently the species called *T. haysii* cannot at present be identified." Simpson's problem with *T. haysii* was that the type locality had been confused by Leidy and the actual locality could not be identified. Thus Simpson (1945) erected a new taxon, *Tapirus copei*, designating a specimen from Port Kennedy as the holotype. Ray & Sanders (1980) thoroughly reviewed Simpson's arguments, and pinpointed the actual type locality of *T. haysii*, making a strong case for the validity of that name. Ray & Sanders (1980) further stated that Port Kennedy is the only population sample of large Pleistocene tapirs from North America. The metapodial figured here (Pl. 1, fig. e) illustrates the size of this species.

Proboscidea

Mastodonts were recognized at Port Kennedy in the earliest papers about the site. The animals were identified as *Mastodon americanum* Leidy, a junior synonym of *Mammut americanum* (Kerr) (cf. Kurtén & Anderson, 1980). The mastodont remains from the site are mostly teeth and indicate a high proportion of juvenile and sub-adult individuals (Pl. 1, fig. g).

Plants

Plant remains were noted in all the early literature on the Port Kennedy deposit. The plants were acknowledged as supporting data in the interpretation of paleoenvironment, but although the vertebrate remains have selectively been reexamined by later workers, no one has published an updated examination of the flora.

Wheatley (1871) pointed out that the Port Kennedy deposit contained two distinct clay units; the lower one red, the upper one black. The plants are represented by numerous well-preserved seeds of a variety of taxa, although beech and hickory nuts are the most abundant. There are many flattened hickory twigs and large pieces of wood of undetermined species. Poor leaf impressions are preserved on a few small blocks of the dark matrix material. *Sphagnum* moss is quite abundant on some of the surfaces of these matrix blocks. Carbonized wood is also present; some of it appears to be charcoal. One of the most remarkable specimens is a whole cone of the pitch pine (Pl. 1, fig. h), blackened but looking as if it had just fallen from a tree.

Mercer (1899) presented a floral list based on identifications by Thomas Meehan and Stewardson Brown of the Academy of Natural Sciences. This list is presented in Table 1 with the taxonomy updated. Meehan and Brown made the observation that the bulk of the hickory and beech nuts were in an immature condition, suggesting that they fell into the fissure in July instead of the autumn when they would be expected to drop. We have not examined the seeds to confirm this observation.

Taphonomy

Taphonomy, as defined, includes everything that has happened to a fossil from the time of the organism's death to its collection or observation in the field. Taphonomy thus describes the environments of alteration and preservation both before and after burial in the sediments, whether the influences be of chemical, mechanical, or biological character.

Were it not for the detailed descriptions of the Port Kennedy deposit, and not simply from the evidence of specimens that survive, we would not be able to describe at any length the taphonomic relationships of the fossils. The collection of 1894-1896, using a grid for data gathering, also opens the way for a more detailed restudy of the original arrangement of many of the Port Kennedy fossils. Although such a restudy is beyond the scope of the present paper, the data remain in the form of specimens and original documentation.

Unfortunately, some of the vertebrate specimens are out of stratigraphic context. Some were part of the original collection of 1870, collected without any kind of stratigraphic control, while others were collected from spoil piles in 1894. Some of the specimens that were collected from the controlled grid in 1894-1896 do not have their corresponding grid coordinates with them.

We recognize some elements of collecting bias among the Port Kennedy fossils. While many fragmentary plant remains exist in the collection, tiny fragments of bone are not common. Only mostly complete or broken bones and teeth survive in the Academy's collections. This typically represents the collection objectives of the nineteenth century, where mostly complete and larger specimens were acquired, and fragments discarded as inconsequential. This is not to fault the collectors of that time, since the value of paleobiological and paleoecological data represented in scrap faunas and microfaunas was unrecognized at that time.

In the Port Kennedy deposit, we have a simple arrangement of deposition: a sinkhole. Transportation and reworking of specimens would not generally be seen as taphonomic processes in such a deposit unless the sinkhole is a drain for some large area, to which material is transported over some distance. In the Port Kennedy sinkhole such a mitigating condition is not detected. Instead, several localized processes are predominant in the interpretation of taphonomy here: gravity (as influencing compaction of sediments and organic remains), mechanical disturbance (by organisms in the sinkhole, by infall of sediments and organisms, and by the abrasion of shifting overburden), and the chemical effects of groundwater and atmosphere. The different kinds of fossils in the deposit are affected differently by these processes, so we discuss the taphonomic observations by fossil group instead of by taphonomic process.

Invertebrates

As noted, coleopterids (Insecta: Coleoptera) are the only representatives of invertebrates in the Port Kennedy deposit. The specimens collected in 1870 were turned over to Horn by Wheatley, but their disposition since then is unknown. Of the specimens, Horn (1876, p. 241) remarked: "[I] made an examination of some masses of clay from which were obtained many fragments of Coleoptera. These remains were of the least destructible portions, and for the most part consisted of the original chitinous material more or less altered, yet retaining in several instances the surface sculpture." The remains consisted of elements as noted in Table 1. Their description is consistent with the kind of preservation expected in such a deposit; namely, fragments of chitinous material. That they were found in the first excavations of the deposit is an indication of their noticeability, although they were discovered in clay removed from the site and prepared with more leisure by Wheatley. The surface sculpture of elytra, necessary for some identifications, was sufficient for Horn to make comparisons with Recent species and for him to establish on them new species. While we cannot vouch for the taxonomic accuracy of these determinations, we can deduce that the material, although fragmentary, was not so severely altered physically or chemically that it was scientifically unrecognizable.

Vertebrates

Practically speaking, two kinds of bone material were encountered in the Port Kennedy deposit—the kind that preserved well, and the kind that did not. The determining factors in preservation are resistance to crushing and the chemical action of groundwater. Apparently, many exquisite specimens were lost in the field for want of appropriate collecting techniques. Wheatley (1871, p. 236) mentioned the first such casualty, a tusk of *Mammut americanum*: "The *tusk* was uncovered for three or four feet in length, and was from five to six inches in diameter, but crumbled into fragments on being moved. The large bones are light cream color, much decomposed, but some of the articulations are very distinct." Workers today, particularly in water-saturated coastal plain formations, can testify to the discouragement of finding perfectly good-looking bone specimens only to have them disintegrate into crumbly or mushy blobs on excavation. The bones have the physical consistency of soft cheese or, as Mercer (1899) described them, "over-ripe pears."

Wheatley (1871, p. 237) reported that the cellular structures of some bones were "usually filled with iron pyrites," a condition that would make specimens susceptible to pyrite disease after exposure to air. We have been unable to corroborate Wheatley's observation; none of the specimens in the Academy's collection exhibit pyritic minerals. Tooth enamel is particularly well preserved, as for example the "teeth and bones of a large Tapirus, the teeth of which retain their white highly-polished enamel" (Wheatley, 1871, p. 237).

Many remarks made by various authors are indications of taphonomic processes. Wheatley (1871, p. 237) was the first to observe that different animals were found in different sediment types in the Port Kennedy deposit: "The remains of

Mylodon, Ursus and Tapirus have been mostly obtained from the tough *red* clay directly under the plant bed, but the remains of rodents, snakes, tortoises, birds, plants and insects, are entirely confined to the *plant bed.*" Cope (1871, p. 73), quoting at length from Wheatley (1871), added the observations: ". . . specimens referred to *Arvicola sigmodus* came from the red bed, and one from the black; one *Megalonyx wheatleyi*, came from the black bed, the others from the red. Milk teeth of Mastodon occur in the red bed also." We nonetheless take note that of the vertebrates, the smaller ones are found predominantly in the dark clay of the plant bed. This may suggest that the taphonomic processes during the red-clay depositional period were insufficient to allow the preservation of more easily decomposed small vertebrate bones.

Cope (1871, p. 93) observed that a specimen of *Lepus sylvaticus* "had an oval mass of carbonaceous matter in its mouth, probably the remains of its unswallowed vegetable food." While this is a plausible scenario, it is more likely that the plant material was worked into the mouth after decomposition of the flesh and compaction of sediments. But it is nonetheless a indicator of contemporary faunal-floral occurrences as well as preservational characteristics of the deposit.

In discussing the number of teeth in a specimen of the ochotonid *Praotherium palatinum*, Cope (1871, p. 94) remarked, "Behind the fourth no trace of tooth or bone could be found on exploring the matrix, though the latter was unbroken . . . ." This indicates deposition of a broken jaw or breakage of the jaw prior to more firm consolidation of the sediments. In turn, breakage of the jaw prior to deposition could indicate that the animal was a prey victim. Another instance of a broken jaw with its pieces in close proximity can point to post-depositional breakage: "the characters of the *inferior molars* are established by three posterior in place in the fragments of jaw held together by the matrix of red sand and clay" (Cope, 1871, p. 78).

Isolated teeth were found in the Port Kennedy sediments, and differences in their preservation allowed Cope (1871) to repatriate various individual teeth as perhaps coming from single individuals. He wrote (Cope, 1871, p. 77) that the molars of *Megalonyx wheatleyi* "are all stained yellowish or light rust color except one, which is black, and which is associated with three posterior molars of similar color and corresponding size. The remaining posterior molars are of the color of the other canine molars, and no doubt belong to the same individuals in part, but none can be associated with the same certainty as the black specimens." Even though various ages of individuals are indicated in the Port Kennedy fauna by degree of bone ossification, according to Cope (1871), we cannot corroborate this. But the relatively unbiased sample of well preserved teeth can permit some reconstruction of age profiles for the different animals represented in the deposit, especially the mastodons.

Regarding the kinds of bones that have been preserved, Cope (1871) made the first observations; for example (Cope, 1871, p. 74): "The bones [of *Megalonyx*] are chiefly those of the feet, with portions of long bones, and numerous vertebrae. Cranial bones are in most instances destroyed, for though several complete crania were exhumed, the exposure to frosts and thaws with snow and rain, as they laid in the piles of material, distintegrated them. Of limb bones there are the extremity of a large tibia with cotylus for astragalus, several extremities of fibulae, and some broken heads of femora."

Other fragmentary bones were seen of less value by early workers, although today their orientation and preservation can be clues toward understanding the taphonomic processes in this sinkhole deposit. For example, Cope (1871, p. 83) commented on "Fragments of many long bones, including many condyles . . . , but in the lack of certainty as to their proper reference, are not described."

Many more examples of useful information to interpret taphonomic processes will be found through the limited literature on the Port Kennedy fossils. A careful comparison of taphonomic indicators with stratigraphic position in the deposit may provide some clues toward the depositional processes and the history of biotic accumulation in the deposit. Such an examination will necessarily await more detailed studies of the surviving material.

Plants

The plant remains vary in preservation from remarkably well preserved, oxidized pine cones—to oxidized, compressed wood fragments—to flat mats of finely ground vegetational debris. Some of the clay pieces contain not only the impressions of leaves, but some of the leaf material itself. On wood pieces, there are no noticeable signs of insect damage. In a footnote, Mercer (1899, p. 281) made an interesting observation of the pine cones (see Pl. 1, fig. h) which reflects on aspects of post-collection taphonomy: "Black, water soaked and flattened almost beyond recognition when found, several of these cones on drying in the warm room at Port Kennedy, to our astonishment, expanded into their natural form."

Wheatley (1871) noted that much of the plant material came from a "plant bed" in dark clay overlying the reddish sediments. We can interpret a quiescent period of aqueous stagnation, allowing the deposition of fine muds in the sinkhole; this perhaps was due to a period of poor drainage. Maturity of the sinkhole's subaerial topography may also be indicated, since poorly sorted, coarser sediments were no longer being deposited. Aside from providing a substratum more conducive to the preservation of plant material, this in turn may also have had an influence on the action of the sinkhole as an animal trap. The presence of more stable sides would both eliminate the number of accidental falls and perhaps be of sufficent repose angle as to allow some fallen animals to clamber back out.

Continued Work

The Port Kennedy deposit is important toward understanding the biotic communities of Irvingtonian northeastern North America. As a sinkhole deposit, it is unique in this time and space, thus it provides a perspective of the biotic communities of the late Irvingtonian of southeastern Pennsylvania. Future paleoecological studies of the Port Kennedy fauna and flora will necessarily have to consider them in their taphonomic context.

With the materials of the 1894-1896 controlled excavation, labelled with grid coordinates, that survive in museum collections—the Academy of Natural Sciences and the American Museum of Natural History—we can begin to reconstruct the depositional patterns of the sinkhole sediments and fossils. We believe that this study would be unique in paleontology. The process will be lengthy and may require taxonomic reexaminations of animals and plants, but it can be concluded with the material that is now available.

Of greater inspiration is the prospect of re-finding the remnants of the sinkhole deposit, which was never completely excavated. It still exists within the buried quarry floor in Valley Forge National Historical Park. We believe we have satisfactorily identified the correct quarry, but no records are available to indicate precisely where the sinkhole is to be found, nor are there records that indicate how deep the fill is in the quarry.

We are of the opinion that an effort should be made to determine the physical aspects of the buried quarry. Seismic profiling can determine the depth and extent of the quarry floor and walls. Modest, portable equipment such as that available to students is probably satisfactory for this purpose. In this regard, it would be a worthwhile exercise for students, even if inconclusive for the purposes of locating the sinkhole deposit. A more expensive and time-consuming process of drilling into the quarry floor could locate the sinkhole precisely—if appropriate sediments (and more conclusively, fossils) are encountered.

Actual reexcavation of the deposit would be the most expensive and inherrently more dangerous operation, one which also would temporarily deface the landscape. Fortunately, the quarry location is not in an area of the national park that is of significant importance to the history of the Continental Army encampment, and neither is it in an area seen by most visitors to the park. We believe that if the deposit can be relocated, controlled reexcavation could provide important information on an inadequately understood part of the biological history of North America.

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